Type of Report: Semi-Annual, July-December 1994.
Alfredo R. Huete, University of Arizona
NAS5-31364

TASK OBJECTIVES

The second half of this year involved detailed assessments of vegetation index (VI) capabilities under a wide variety of "external" measurement conditions representative of MODIS orbits. Presentations made at the IGARSS'94 Symposium and AGU meetings involved studies on the bidirectional (anisotropic) properties of vegetation indexes; atmospheric interactions with the VIs; and VI behaviors over a broad range of land surface cover types. The VI-ATBD was revised and re-submitted to the Science Project Office. Current efforts now involve linking the various algorithm modules to the VI algorithm for a more complete end-to-end testing.

WORK ACCOMPLISHED

1. Vegetation Index ATBD Peer Review

The peer review panel questioned the need for an atmospheric-resistance component in the VI algorithm, under the presumption that MODIS data will already be corrected for atmosphere. MODIS data will be corrected for atmospheric aerosols to the best ability possible at much coarser spatial resolution (50 to 500km). The performance of the atmospheric correction algorithm will be dependent upon the finding and relative locations of dark objects'. Thus, it is doubtful that an operational atmospheric correction can be applied consistently on a global basis. It is more likely that a dark object subtraction will be performed in certain areas and a mean sky climatology approach implemented in other regions where dark objects are unavailable. This may alter the integrity of the vegetation index and thus the atmospheric resistance component may still be advantageous in improving the performance of the vegetation index algorithm.

Preliminary processing of Landsat Thematic Mapper (TM) images over BOREAS, the OTTER transect in Oregon, and over Walnut Gulch, Arizona show the atmospheric resistance component to the VI, which is accomplished pixel by pixel, to very effectively remove smoke plumes, subpixel clouds, and light cirrus clouds, whereas the atmospheric correction algorithm was unable to remove such effects since the spatial resolution of these sources of atmospheric contamination are well within the 50km resolution limit of the atmospheric algorithm. Lastly, the atmospheric resistance component to the VI is independent of the degree to which the raw data is atmospherically corrected. Thus, whether the data is corrected for gases, aerosols, or both has minimal effects on the VI. A detailed and comprehensive assessment to the above statements is underway as part of 1995 activities.

Further comments from the ATBD Peer Review Panel concerned the correction for canopy background. The primary concerns included; (1) the soil correction was only valid for sparsely vegetated areas, (2) the correction may cause additional problems at the expense of soil correction, and (3) it is more common to find littered surfaces rather than bare (exposed) soil. The first and last concerns are due to misunderstandings. The papers written on soil correction show that soil problems in VIs are not due to the bare soil but instead are due to vegetation-background multiple scattering, primarily of near-infrared photons. Because of this NIR scattering, simple ratios like the NDVI cannot "ratio" out such effects since red photons are not scattered but absorbed. Consequently, whether the background is soil, litter, snow, water, etcc, is inconsequential to the problem at hand. Only the brightness' of the background is important with snow causing the most serious problem. Secondly, because this is a first-order scattering problem it is the plant canopies of medium density (or green cover) that are most affected. By comparison, sparsely vegetated canopies are not seriously affected since there is not sufficient plant cover to cause first-order scattering.

The second concern is very important and is currently of high priority in our VI analyses. It iscertainly possible that new problems may be encountered by departing from a simple ratio approach. One of these is topography as well as angle of illumination. The advantage of the unaltered NDVI would be that it would tend to cancel out illumination and topographic variations. In theory, however, this is not exactly true since such effects can only be ratioed out if the surface is Lambertian. Thus, the inherent anisotropy of vegetated surfaces negates the ratio approach. Nevertheless, the ratio approach may be the best approximation to this problem and thus this needs much more careful attention.

2. Biophysical Coupling of the VI's

Following suggestions from the ATBD Peer Review Panel, more emphasis is being placed in deriving biophysical products from the VI equations. Leaf area index (LAI), absorbed photosynthetically active radiation (APAR), and %ground cover parameters are being linked to the VI equations in an effort to assess VI linkages and sensitivities. The role of land cover type in controlling the VI - biophysical relationships is also being investigated with both simulated and experimental data sets. It appears quite definite that these relationships are land cover type dependent and will require a set of equations for each land cover type or biome.

The primary direction for MODIS derivation of biophysical parameters has also shifted toward a more direct derivation of these parameters from look-up-tables based on Myneni canopy model simulations. This effort will utilize spectral reflectances as input and is being directed by Dr. Steve Runnings group. The VI-biophysical coupling will serve as a backup to this effort and will also serve as part of the VI - validation effort.

3. SDST simulation meeting

The meeting at Flathead Lake, Montana was very useful in raising issues related to the data integration and inter-dependencies of the Modland algorithms. Wim van Leeuwen from our lab participated. The data dependencies were scrutinized carefully and potential uses of data which can both test the algorithm and software code were discussed. The responsibility for generation of such data sets belong to the team members and not to SDST, however, through the discussions at the meeting it became evident that many data sets can be shared. The dependencies of the VI algorithm to the atmospheric correction, BRDF, DEM, surface reflectance products became evident and a manner in which these separate algorithms can be linked to the VI implementation is being worked on now. Currently our projects involve each of the major VI dependencies on other products; namely VI - atmosphere studies, VI - topography issues, VI - BRDF algorithm development, and VI - biophysical studies.

4. AGU meeting

A special joint session on vegetation indexes was convened at the American Geophysical Union's Fall Meeting in San Francisco, December, 1994. Dr. Michel Verstraete and myself were co-conveners under session H28, entitle "The Design and Evaluation of Remote Sensing Spectral Indices for Terrestrial Applications". The goals of this session were nicely met with very useful and constructive dialogues. The objectives were written as:

Vegetation indices are the most commonly used tools to analyze satellite remote sensing data in the solar spectral range, whether to identify the type or to estimate the properties of the targets being observed. While these indices have obviously permitted major advances in the operational use of such data, they are notoriously sensitive to many other perturbing effects such as soil brightness variations, changes in atmospheric state and composition, or the geometry of illumination and observation. Future calibrated instruments on the NASA EOS and ESA ENVISAT Earth observation polar platforms will feature much improved spatial, spectral and directional resolutions. They provide the opportunity to design advanced spectral indices better adapted to particular applications or less sensitive to some of theundesirable perturbations. The proper biophysical interpretation of existing and new indices must also be investigated. Papers are solicited on the design and evaluation of spectral indices in general and vegetation indices in particular. Contributions focusing on comparing the performance of existing indices, or on their interpretation are also encouraged.

5. SCF Activities

5.1. Walnut Gulch, ASAS Data

Hongyan Liu (Ph.D. candidate) completed processing ASAS imagery acquired during the dry and wet seasons of 1991 over the Walnut Gulch Experimental Watershed in southeastern Arizona. This data set includes 7 multiple view angles along both principal and orthogonal planes to the sun, at both large and small solar zenith angles, and over semi-desert grassland, mixed grass-shrub, and riparian forest (mesquite bosque) sites. The 29 band data were reduced to the first 4 MODIS bands and VIs calculated with and without atmospheric correction. This data set is being used to examine the VI anisotropy behavior and the consequences to level 3 processing of the VI into a 10-day composited product. Preliminary results from this data set were presented at the IGARSS'94 Symposium in Pasadena, August 1994. Results showed considerable anisotropic behavior for all VIs examined. Consequently at level 3 production, this directional effect will have to be accounted for.

Concurrently, the OTTER - ASAS data set has also been processed in a similar way as the Walnut Gulch data. Eight sets of images including 7 view angles were analyzed over the OTTER transect. The OTTER data is providing us with a richer variety of land cover types over more dense, forested conditions with LAI values approaching 10.

5.2. U.S.A - Mexico Thematic Mapper Data

The 8 Landsat TM images acquired over the Walnut Gulch Experimental Watershed in 1992 have been reprocessed into MODIS images through the use of the MODIS-View program provided by the SDST team. The bands have been resampled to 250m and 500m resolutions and VIs calculated. All 8 images were co-registered and a Rayleigh and ozone atmospheric correction performed. This data set is being used to study spatial and temporal variations along the U.S.- Mexico border. This data set has also been sent to Dr. Alan Strahler at Boston University as part of the Land Cover data set for algorithm development and testing. The sites include grassland, shrubland, degraded mesquite- grassland, riparian zones, and conifer covered mountain areas. For VI purposes it is of interest to determine if differences in vegetation across the border (associated with land use practices) are detectable with VIs. Despite clearly evident visual differences in color composite imagery and in brightness', single channel images, none of the VIs thus far has shown any differences in vegetation across the border. A ground truth campaign is currently under way but preliminary results show distinct differences in vegetation conditions on both sides of the border. On-going research includes an analysis of the 30 meter data set and a review of the atmospheric correction and calibration procedures. Ground truth information will provide us with some measures of VI resolution and performance capability.

5.3. NIGER-HAPEX ASAS Data

Wim van Leeuwen, a Ph.D. student is integrating his biophysical and field radiometric measurements acquired at HAPEX-

Sahel with concurrently acquired 1992 ASAS imagery. He is attempting to model ASAS pixel responses with in-situ hemispherical reflectance factors of "pure components" (leaf, litter, soil, bark, etc), measured with an integrating sphere, and combined with the SAIL model to generate canopy (structural) spectra at varying LAI conditions. He is also utilizing field measured spectra of the canopies for the same purpose.

Currently he is working on a SAIL- model generated canopy data set with the presence of litter and bark. The litter is being placed within the canopy in three arrangements; (1) on the soil surface producing a canopy background consisting of litter; (2) randomly placed within the canopy resulting in mixtures' of green and litter vegetation; and (3) over the canopy producing a canopy data set whereby last year's growth stands over new emerging green vegetation, a situation common in perrenial grasslands that are not overgrazed. The canopy data set is being used to study VI relationships with leaf area index and fraction of intercepted photosynthetically active radiation (FIPAR) for the range of vegetation conditions. Current results show that the presence of bark and litter alter the estimates of FPAR considerably. A mixture model is also being applied to the data set with the aim of removing litter influences on vegetation calculations.

5.4. Walnut Gulch Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data.

Karim Batchily (program coordinator) is working on the second segment of processing of the 1991 AVIRIS imagery acquired over Walnut Gulch Experimental Watershed. He presented the results of the first segment at the annual meeting, Soil Science Society of America (SSSA) on November 14, 1994. On-going work in this area include simulation of MODIS imagery from AVIRIS, and the use of mixture models to test and validate the VI algorithm. In collaboration with Dr. Erzsebet Merenyi of the Lunar and Planetary Lab at the University of Arizona, they are producing both neural-net and mixture model based classifications of the scene components which include semi-arid grassland, mixed grass-shrub, and desert shrub plant communities underlain by a complex pattern of soil types including basalts, and calcic and iron rich soils. The spectral data is being integrated and compared with both ASAS and TM imagery over the same area for studies related to scale and spectral dimensionality analyses. We hope that this provides an opportunity to investigate the synergistic uses of multiple sensors for large scale soil and vegetation mapping.

5.5. AVHRR Study Sites

Hongtao Jin (Master's degree student) continues to work on the 8 km daily AVHRR pathfinder data set to investigate the compositing procedure of the vegetation index and to study the multi-temporal behavior of VI data over a large range of land cover types over the various sites of the Chinese Ecological

Research Network (CERN). He is comparing land cover classes obtained through several multivariate schemes, including mixture modeling to separate unique sources of temporal variation.

5.6. Myneni Radiative Canopy Model

José Epiphanio (Post-doctorate) presented his work on VI relationships to absorbed photosynthetically active radiation (APAR) and leaf area index (LAI) in growth and productivity models. His results are being presented at the IGARSS'94 Symposium in Pasadena, August 1994. He utilized the Myneni canopy model, in conjunction with 6S' atmospheric radiative transfer model to simulate the optical properties of both uniform and heterogeneous vegetated surfaces. It appears that there may be two classes of VIs, one of which is sensitive to 2-dimensional canopy parameters like FPAR and %green cover, while the other is more related to 3-dimensional parameters like LAI and biomass.

5.7. Global Land Cover Test Sites

I met with a group of professors from the Universidad de Chile which are involved in global change issues and the use of GCM models in conjunction with remote sensing. We discussed the GLCTS program and they are very interested in participating. Apparently they have already been collecting 1km AVHRR over their sites for the last 10 years. Chile is rather unique in that there is a tremendous gradient of climates and vegetation types in short (500km) east-west distances as one proceeds from the coasts and upland valleys to the Andean Mountains. Thus one can study a great variety of land cover types over single "test sites". As the country is also rather long, it traverses through a wide range in latitudes from tropical to the southerntip. Hence the reason for 6 sites. As I plan to visit Chile for a soils meeting in April 1995, they have offered to show me as many sites as time permits. The sites selected include:

Site 1. Coquimbo, 30S lat./ 71.2W long. , Path 01 Row 81 Landsat 4 WRS. This site has an environmental monitoring program in place. It has 100mm precip near the coast, Mediterranean climate with high seasonality and winter precip in May-Sept.

Site 2. Santiago, 33.5S lat./ 70.7W long., Path 233 Row 83. Mediterranean climate, 300mm precip., irrigated plains, grassland, dryland agriculture. Has 2 monitoring stations.

Site 3. Talca, 35.5S lat./ 71.5W long., Path 233 Row 85. Mediterranean climate, 750-1500mm precip., Temperate forest. Has a monitoring station.

Site 4. Osohno, 40.5S lat./ 73W long., Path 233 Row 88. Humid climate, 2000mm precip., Grassland/ Forest land cover types, both of which are "green" all year round. Has monitoring station.

Site 5. Copiapo, 27.5S lat./ 70.6W long., Path 01 Row 79.

This site is at the border between pure desert (Zero precip.) and the start of the xerophytic vegetation zones. There is no current on-site monitoring station but there is a 10 year, on-going vegetation monitoring program for biomass research. Mediterranean climate.

Site 6. Lauca National Park, 18.5S lat./ 69W long., Path 01 Row 73. This is on the Altiplano and represents a high mountain ecosystem. This is a huge park, managed by COMAF (Forest Service) with monitoring station. The Altiplano extends into Bolivia.

5.8. Papers Presented

i. W.J.D. van Leeuwen, A.R. Huete, and C.L. Walthall, "Biophysical interpretation of a spectral mixture model based on a radiative transfer model", IGARSS'94 Symposium on August 8-12, 1994, in Pasadena, California.

ii. G.R. de Lira, K. Batchily, J. Hongtao, and A.R. Huete, "Optical and seasonal variations along the U.S-Mexico border: an analysis with Landsat Thematic Mapper imagery", IGARSS'94 Symposium on August, 8-12, 1994, in Pasadena, California.

iii. J.C.N. Epiphanio, A.R. Huete, and H. Liu, "Influence of sun-view geometries on the relationships among vegetation indices, LAI, and absorbed PAR", IGARSS'94 Symposium on August 8-12, 1994, in Pasadena, California.

iv. H.Q. Liu and A.R. Huete, "A system based modification of the NDVI to minimize soil and atmospheric noise", IGARSS'94 Symposium on August 8-12, 1994, in Pasadena, California.

v. Batchily, A.K., Huete, A.R., Merenyi, E., Hongtao, J., Accioli, L., and de Lira-Reyes, G., "Extraction of soil information from remotely sensed semi-arid areas with mixture models", American Society of Agronomy, Seattle, WA, Nov. 13-18, 1994.

vi. Epiphanio, J.C.N., and Huete, A.R., "Effect of soil red and NIR reflectance contrast on vegetation indices", American Society of Agronomy, Seattle, WA, Nov. 13-18, 1994.

vii. Huete, A.R., Liu, H.Q., and Justice, C.O., "Simulation of MODIS vegetation index imagery from Landsat TM over different biomes", American Geophysical Union Fall Meeting, San Francisco, CA., Dec. 4-9, 1994.

viii.van Leeuwen, W.J.D., Huete, A.R., and Walthall, C.L.,"Biophysical interpretation of a linear spectral mixture model at HAPEX-Sahel", American Geophysical Union Fall Meeting, San Francisco, CA., Dec. 4-9, 1994.

ix. Epiphanio, J.C.N., and Huete, A.R., "Soil and litter reflectance contrast effects on vegetation indices and their relationship to fAPAR", American Geophysical Union Fall Meeting, San Francisco, CA., Dec. 4-9, 1994.

5.9. Meetings

i. I attended an Inter-American Institute (IAI) "Workshop on Comparative Studies of Temperate Terrestrial Ecosystems" on July 26-29, 1994, in Durham, North Carolina. This workshop is hosted by the Inter-American Institute for Global Change Research. The objective of the workshop is the development of regional scientific plan to further global science research and impacts on natural and social systems.

ii. I attended, by invitation, the "Second Workshop on Spectral Mixture Analysis" on August 15-17, 1994, at the University of Washington in Seattle. The objective of this workshop is to compare state of the art' mixtures methodologies and assess future directions in mixture modeling.

iii. Wim van Leeuwen attended a HAPEX-Sahel meeting in Toulouse, France on November 14-15, 1994.

ANTICIPATED FUTURE ACTIVITIES

1. SCAR-B Field Experiment

The Smoke, Clouds and Radiation Experiment (SCAR-B) in Brazil appears to be all set to begin this August. A tentative science plan has been made and as part of the land component we plan to make in situ measurements of vegetation properties over a variety of land surface cover types, both before and immediately after a burn event. We plan on using MAS and AVIRIS data, light aircraft radiometric measurements with the INPE plane, satellite data from Landsat TM, AVHRR, and possibly SeaWifs, and ground-based radiometric and biophysical (soil & plant) measurements for level 2 and level 3 VI algorithm development, testing, and validation. The SCAR-B experiment will satisfy several goals for the Vegetation Index algorithm;

(1) measurements made over various land cover types will provide information on the capability of VIs in distinguishing spatial variations in biophysical plant properties,

(2) measurements conducted before and after burn events will provide a measure of VI sensitivity for change detection resulting from pertubations in the vegetation cover (disturbances being related to degree and intensity of the fire),

(3) measurements conducted over clear and contaminated (smoke, aerosols) atmospheric conditions will allow us to analyze the atmospheric resistance component to the VIs,

(4) measurements of APAR, LAI, canopy transmittance, and ground

cover will advance biophysical - VI linkages over various land cover types,

(5) altered canopy backgrounds due to variations in ash, litter, and exposed soil will allow an assessment of canopy background problems over the various land cover types, and

(6) the 45¯ scan width of MAS will provide some bidirectional VI data which will allow us to advance the development of the VI compositing algorithm.

2. SPOT- VEGETATION

The Modland team is working with Dr. Gilbert Saint representing the new SPOT-VEGETATION sensor in development. In response to Dr. Saint's presentation at the October Science Team Meeting, Modland has agreed to become an official partner of the program with the aim of furthering global vegetation-related studies. As part of Modland, I may attend SPOT team meetings and we may submit a proposal for the second phase of their research program in late 1995.

3. SeaWifs data processing

Depending on the launch date and operational data stream of SeaWifs, we plan on processing a limited amount of land-based SeaWifs data into vegetation index products for testing and comparison of global fields of the VI. The GIMMS group at NASA/GSFC under the supervision of Chris Justice will process some of the SeaWifs data. The SeaWifs sensor will provide the blue band which will enable some of the atmospheric resistant components of the VI's to be tested on a global and regional basis.

PUBLICATIONS

Huete, A.R., Liu, H., 1994, "An error and sensitivity analysis of the atmospheric- and soil-correcting variants of the NDVI for MODIS-EOS", IEEE Trans. Geoscience and Rem. Sens. 32: 897-905.

Liu, H., and Huete, A.R.,1995, "A feedback based modification of the NDVI to minimize soil and atmospheric noise", IEEE Trans. Geoscience and Rem. Sens. (in press).

Running, S.W., Justice, C., Salomonson, V., Hall, D., Barker, J., Kaufman, Y., Strahler, A., Huete, A., Muller, J.P., Vanderbilt, V., Wan, Z.M., Teillet, P., Carneggie, D., 1994, "Terrestrial remote sensing science and algorithms planned for EOS/MODIS", Int'l .J. Rem. Sens. (in press).

van Leeuwen, W.J.D., Huete, A.R., Duncan, J., Franklin, J., "Radiative transfer in shrub savanna sites in Niger: preliminary results from HAPEX-Sahel: 3. Optical dynamics and vegetation index sensitivity to biomass and plant cover", 1994, Agric. &

Forest Meteorol. 69:267-288.

Begue, A., Roujean, J.L., Hanan, N.P., Prince, S.D., Thawley, M., Huete, A., and Tanre, D., 1995, "Shortwave radiation budget of Sahelian vegetation during HAPEX-Sahel - 1. Techniques of measurement and results", Agric. & Forest Meteorol. (Submitted 9/94).

Epiphanio, J.C.N, and Huete, A.R., "Dependence of NDVI and SAVI on sun/sensor geometry and its effect on fPAR relationships in alfalfa", Rem. Sens. Environ. (in press).

van Leeuwen, W.J.D., Huete, A.R., Walthal, C.L., Prince S.D., Hanan, N., Begue, A., and Roujean, J.L., 1995, "Deconvolution of remotely sensed spectral mixtures for retrieval of LAI, fPAR and soil brightness", J. Hydrol. (Submitted 10/94).